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SCHOOL OF ENGINEERING & APPLIED SCIENCE
PLASMA LABORATORY

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Re: NsG-302-63

Gentlemen:

This is the final report on the research grant NsG-302-63 entitled "Theoretical Research Investigations in Plasma Physics and Magnetogasdynamics." This research resulted in a doctoral thesis (P. Koch) and two published papers. The results are summarized as follows:

Radiative Shock Wave Structure (P. Koch)

A study is made of plane gas dynamical and transverse magnetogasdynamic shock waves in fully ionized hydrogen, at conditions such that radiative processes are significant. An established steady state flow is found to exist for these waves only in astrophysical cases, since the wave thicknesses in such a flow are quite large. In the case of such an established flow the Rankine-Hugoniot jump equation (i.e., the relationship between the flow variables in the initial and final states) is analyzed and then solved numerically. It is shown that of the twelve roots of this equation only two are physical, corresponding to the supersonic initial and subsonic final states.

The differential equations which describe the above shock waves are analyzed. The result is a set of four simultaneous nonlinear ordinary first order differential equations, the solution of which gives the structure of the shock, i.e., the dependence of the flow variables on position within the shock wave. The structure equations are solved numerically for cases where the shock is optically thick, i.e., the mean free path for absorption of radiation is much smaller than the characteristic lengths for change of the flow variables. This is called the Eddington or diffusive approximation. A new criterion is given for the validity of this approximation in terms of the shock itself, independent of the properties of the atmosphere. Numerical results of radiative shock structure in this approximation are given.

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This work is published as Dr. Koch's doctoral thesis, Dept. of Physics, Columbia University, June 1964, and as Columbia Plasma Laboratory Report #10, June 1964. These research results will be submitted to the Physics of Fluids Journal.

Geomagnetic Micropulsations (A. Sen)

A thorough analytical study of the transmission of very low frequency waves from the exosphere down to the surface of the earth has been nearly completed. It is seen that for these waves the path between exosphere ($\sim$64,000 km) and an altitude of approximately 250 to 500 km behaves as a highly inhomogeneous, almost lossless hydromagnetic medium. Between an altitude of 250 to 500 km and 80 km, the character of the waves radically change due to highly increased collision of ions with neutrals. Below an altitude of 80 km the waves are transformed into electromagnetic waves, which travel down to the surface of the earth. The inhomogeneous hydromagnetic medium can be considered to consist of several sections, each with an exponential variation of wave impedance. Exact analytical solution of the transmission through a medium with an exponential variation has been obtained. The path between 250 to 500 km and 80 km has been modelled by a homogeneous dissipative layer and a layer of vacuum. Matching the solutions at each interface between sections or layers, the total transmission coefficient is obtained as a function of frequency. The outstanding feature of the results is that the transmission path is a very effective filter, not only in the sense of a medium providing dissipative attenuation, but also in the sense of band pass reactive structure. Hence, the reception of micropulsations on the surface of the earth is strongly dependent on the state of the transmission medium. The latter is affected by solar wind conditions. Numerical calculations based on typical conditions are now being done. A paper on this work will be written up in the immediate future.

Plasma Stability (A. Sen)

The effect of compressibility on Kelvin-Helmholtz instability in a plasma has been studied under partial support of this contract. The effect of compressibility on the stability is brought into focus by considering two limiting cases: a very stiff plasma (of very small compressibility) and a very lumpy one (of very large compressibility). It is found that unlike surface tension, gravity and magnetic field, compressibility can have either stabilizing or destabilizing effect, depending on the stationary state of motion. In general, this may lead to two domains of stability, in contrast to only one that may exist in the case of incompressible plasma. A paper entitled "The Effect of Compressibility on

Kelvin-Helmholtz Instability in a Plasma" by Amiya K. Sen has been accepted for publication in the Physics of Fluids Journal.

Sincerely yours,

Robert A. Gross

Robert A. Gross
Professor of
Engineering Science

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